One quasiparticle configurations in Lanthanum isotopes

Nithu Ashok[1],* Deepthy Maria Joseph[1], and Antony Joseph[3]
[1]Department of Physics, University of Calicut, Malappuram, Kerala, INDIA

Introduction

Experimental facilities available nowdays help us study wide range of the unexplored part of nuclear landscape. The nature of neutron rich nuclei away from beta stability line is still a matter under investigation. Study of nuclei there mainly rely on theoretical methods. Since the study of odd nuclei is a very challenging task, less studies have been conducted in this area. The presence of odd mass nuclei breaks the time reversal symmetry, which makes the theoretical calculations more difficult. A recently developed method which is an approximation to the exact blocking, called Equal Filling Approximation(EFA)[1], serves better in this case. In EFA, the unpaired nucleon is treated in an equal footing with its time reversed partner. i.e, the unpaired nucleon is assumed to occupy half in a given orbital and half in its time reversal partner. Thus it preserves the time reversal symmetry. In the present study we have made an attempt to investigate systematically the one-quasiparticle states in odd-A La isotopes.

Theory

For the present study we have adopted the Hartree Fock Bogoliubov(HFB) theory[2]. The ground state wave function of an even-even system is given by the quasiparticle vacuum condition, i.e, $\beta_\mu|\Phi>=0$. In the case of odd nuclei ground state is given by one quasiparticle excitation,$|\Psi>=\beta^\dagger_{\mu_B}|\Phi>$.

For the treatment of odd nuclei we adopted the EFA. In EFA, for preserving time reversal symmetry, the state μ_B and its time reversal partner $\bar{\mu}_B$ are included with equal status in the density matrix ρ and the pairing tensor κ[3]. The final HFB equation is given by,

$$\begin{pmatrix} h^{EFA} & \Delta^{EFA} \\ -\Delta^{EFA*} & -h^{EFA*} \end{pmatrix} \begin{pmatrix} U_n \\ V_n \end{pmatrix} = E_n \begin{pmatrix} U_n \\ V_n \end{pmatrix} \tag{1}$$

The total HFB-EFA energy is given by

$$\begin{aligned} E^{EFA,\mu_B} =& Tr[t\rho^{EFA,\mu_B}] + \frac{1}{2}Tr[\Gamma^{EFA,\mu_B}\rho^{EFA,\mu_B}] \\ & - \frac{1}{2}Tr[\Delta^{EFA,\mu_B}\kappa^{EFA,\mu_B}] \end{aligned} \tag{2}$$

In the mean field part we have employed the zero range Skyrme interaction with SIII, SKP and SLY5 parametrizations and in the pairing part density dependent delta interaction in its mixed form is used[4]. The Skyrme HFB equation is solved by using cylindrically symmetric harmonic oscillator and transformed harmonic oscillator basis[5].

Results and Discussion

An odd nucleus is picturised as even-even core plus an unpaired nucleon. We have selected isotopes of La away from beta stability line ranging from A=151 upto 2n-dripline. Here Ba isotopes are taken as the e-e core. The unpaired nucleons or the quasiparticles are labeled by Nilsson quantum numbers $[Nn_z\Lambda]\Omega$. Calculations are performed by selecting all the possible quasiparticle states near to the Fermi level. The state with minimum HFB energy is considered as the ground state. Fig.(1) illustrates the quasi particle excitation energy for some relevant states. The hole states are plotted below and particle states above the ground state. From Fig.(1) we can see that the change of basis does not produce much difference in the energies of quasiparticle states except for certain isotopes. But quasiparticle energies are highly sensitive to the choice of Skyrme forces. For eg. in the case of ^{157}La we obtained [420]1/2+, [422]3/2+ and [550]1/2- as the ground state

*Electronic address: nithu.ashok@gmail.com

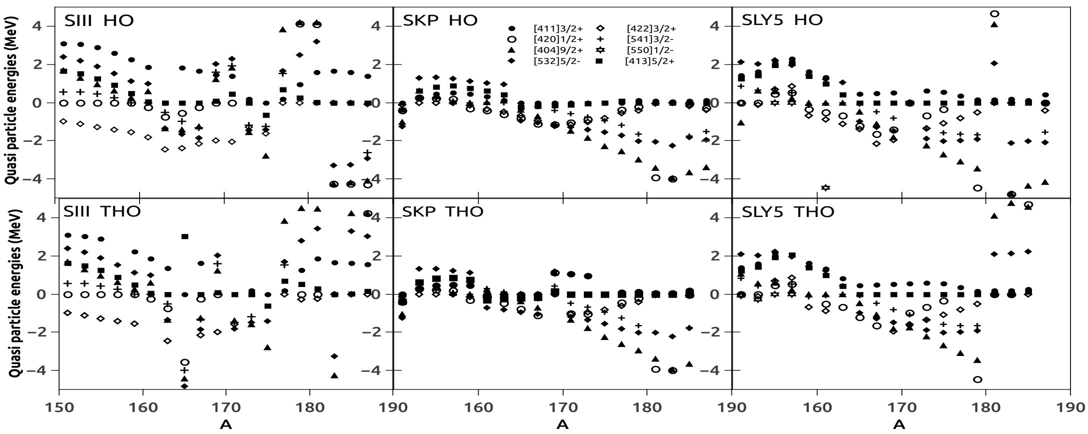

FIG. 1: One quasi particle energies for different Skyrme forces in La isotopes.

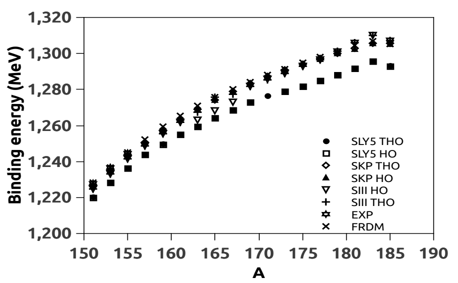

FIG. 2: Plot of binding energy vs mass number.

for SIII, SKP and SLY5 respectively. Similar observations are obtained for other isotopes also. For certain isotopes, ground states of SIII and SLY5 matches. In the case of SIII, ground state of $^{151-157,169,171}$La corresponds to [420]1/2+, $^{163-167,173,183,185}$La corresponds to [413]5/2+. In SKP, ground state of $^{151,165-177}$La, $^{179-185}$La corresponds respectively to [411]3/2+, [413]5/2+. For SLY5, we get [420]1/2+, [404]9/2+, [413]5/2+ as the ground state for ^{151,152}La and $^{159-163}$La, ^{177,183,185}La respectively. The mismatch of energy between different Skyrme parameters can be accounted with the difference of the effective masses. The level density of single particle states is related to the effective mass and low effective mass leads to the stretching of single particle energy levels [6]. Mean field theory gives only a qualitative description of one quasiparticle spectra. In Fig.(2) we have plotted the binding energies corresponding to the obtained ground states and are compared with available experimental values and FRDM results. Since the experimental values are not available we can't conclude which parametrization describes the quasiparticle states the best.

Acknowledgements: One of the authors(Nithu Ashok) gratefully acknowledges UGC for financial support under JRF scheme.

References

[1] S. P. Martin and L. M. Robledo, Phys. Rev. C, **78**, 014304(2008).

[2] P. Ring and P. Shuck, *The Nuclear Many-Body Problem*, (Springer, Berlin, 1980).

[3] N. Schunck, J. Dobaczewski, J. McDonnell, J. More, W. Nazarewicz, J. Sarich and M.V. Stoitsov, Phys. Rev. C, **81**, 024316(2010).

[4] J. Dobaczewski, W. Nazarewicz and M.V. Stoitsov, Eur. Phys. J. A, **15**, 21(2002).

[5] M.V. Stoitsov, N. Schunck, M. Kortelainen, N. Michel, H. Nam, E. Olsen, J.Sarich, S. Wild, Comp. Phys. Commun.,**184**, 1592(2013).

[6] A. V. Afanasjev and S. Shawaqfeh, Phys. Lett. B, **706**, 177 (2011).